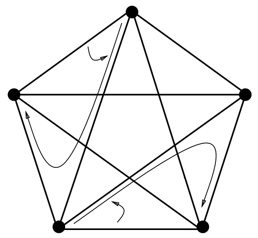
Communications Research in the Department of Mathematics

The communications industry is rapidly growing and continually introducing new technologies and services. The industry relies upon the invention and application of new mathematical tools, ideas and insights to solve many of the most challenging questions posed by this technology.

Several members of the Department's Statistical Laboratory have been active in developing mathematics for the industry. Their work has included both fundamental research, supported by bodies such as the EPSRC, and also collaboration in technology transfer with operators, such as BT and AT&T. It has resulted in patents and numerous research papers.

The following are examples of a few of the challenging issues in communications that are presently being studied by staff in the Laboratory.

- Cost effective network management
- Design and control of reliable and robust networks
- High-speed, high-performance, multi-service networks
- Charging and accounting for network services
- Provision of advanced multi-media user applications



Multi-service networks

Modern communication networks (such as ATM) are designed so that one physical network can simultaneously carry many different services, (voice, video-telephone, Internet, bank account access, etc.) These services compete for the same resources, but have very different statistical patterns, bandwidths and quality of service requirements. It is important to know how to quantify these requirements and to work out how best to respond to users' demands in cost effective ways.

Pioneering research at Cambridge has shown that the the notion of an 'effective bandwidth' can be used to correctly assess the network resources required by sources of differing characteristics, and to explain how such sources can be 'statistically multiplexed' on the same physical network. These ideas are expected to play a central role in the future development of multi-service networks. Our current research focusses on applying the ideas of effective bandwidth to issues of congestion control, routing, policing and tariffing.

Marketed-oriented issues

An important current theme in telecommunications is the increasing trend towards market-orientated solutions. Pricing structures are likely to have a major effect on the performance and control of multi-service networks. Most current data arises from users that are not charged and not policed. It is expected that as tariffs are introduced that permit users to choose amongst differing levels of service and policing, then users will shape their activity in response to the tariff structure. This will affect traffic characteristics and the potential for statistical multiplexing.

The choice that a user makes from a menu of available services and tariffs is likely to give important indirect statistical information on that user's type of traffic, as well as direct information on the user's required bandwidth and quality of service. A good tariff structure will encourage users, through economic benefits, to provide the network with the information which it needs to perform the essential tasks of estimation and admission control.

Game theoretic concepts can be integrated with network performance models to address issues concerning with modelling the interactions between customer behaviour and network tariffs. Other interesting questions concern the economic advantages accruing from coalition s of international network operators and questions of transit fees between operators.

Although vitally important, most of these issues are as yet poorly understood. Current work in the Statistical Laboratory is aimed at developing models which will provide an understanding of these issues and their interrelationship.

Modelling of distributed systems

In a communications network the data and control intelligence are distributed throughout the physical network. It is important to understand how best to distribute the data and how to balance the communication overhead between network components. Important advances have been made in the use of parallel computers in the physical sciences to model distributed systems with a highly regular structure. Current research is aimed at realising similar success in modelling communication networks in which the structure is less regular.

Multi-media applications

The world is witnessing a phenomenal growth in the introduction and usage of multimedia applications that run over broadband multi-service networks. A few examples are: teleconferencing, shared white-board and video on demand. On the Internet, the World Wide Web, a hyper-media distributed system, is already used by millions of people and has a substantial global business potential for retailers and others to provide products and services which can be charged to a customer's credit card.

An important type of optimization problem originates from asynchronous data accesses, which can be seen as one of the key functions of multi-media networks. This is particularly clear within the Web framework, where huge amounts of data are accessed and transferred daily over the Internet. Among the interesting problems posed are the optimal location of caches for the pages which are known to be accessed most frequently, the design and evaluation of novel cache replacement algorithms that take into account the geographically distant nature of the Web data repositories, and the determination of efficient distributed algorithms for ensuring the consistency of the various caches, when these can be updated asynchronously.

Mobile communications

The field of mobile communication systems is rapidly expanding. The spacial properties of these systems pose specially interesting questions and, in particular, modelling tools are needed that can deal with spatial information. A promising line of enquiry, which is being pursued in the Department, is to interface methods of network analysis with Geographical Information Systems (GIS).

Security, scheduling, algorithms, data modelling

Staff in the department have interests in other areas of mathematics that are applicable to the telecommunications industry. These include the mathematics of security, coding, and secure data transmission; queueing control; scheduling; algorithms and computational complexity; dynamical systems (including the behaviour of chaotic systems); and statistical modelling of time series data.

R.R. Weber, 24.02.95